Utilizing CAPT and COSP to Analyze Arctic Clouds in CAM4 and CAM5

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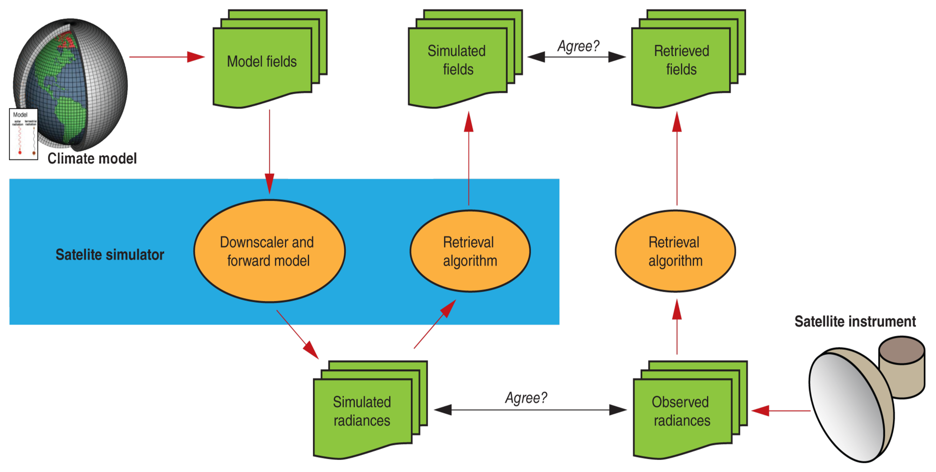
New Techniques for Examining Arctic Clouds in Climate Models

It is important to correctly model Arctic clouds because they are a major controller of the Arctic surface radiative budget, differences in modeled Arctic clouds help explain differences in Arctic climate projections, and the melting sea ice affects Artic cloud properties. This study introduces new techniques for examining Arctic cloud variability and comparing observed Arctic clouds to climate model output. These new techniques include:

- Examining domain wide Arctic cloud observations on synoptic time scales during specific dynamics and thermodynamics
- Examining the covariability between Arctic clouds and surface type by sub setting Arctic dynamics and thermodynamics
- Examining Arctic clouds using active remote sensing
- Using COSP output and the CAPT framework to compare observed Arctic clouds to climate model output

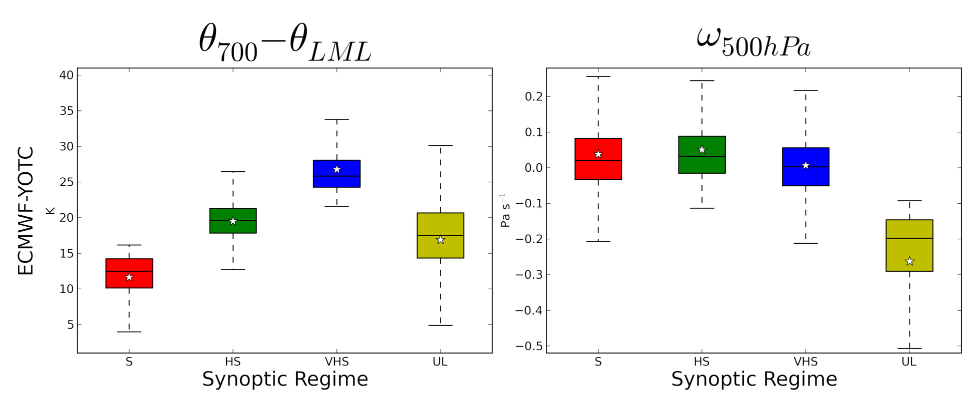
We run two recent atmospheric components of the Community Earth System Model, CAM4 and CAM5, using the Cloud-Associated Parameterization Testbed (CAPT) framework from May 2008 to March 2010. Each run is initialized at 00Z and run for multiple days. We initialize the models with the European Center for Medium Range Forecast operational output for the Year of Tropical Convection (ECMWF-YOTC). Day 2 output is examined, and model output analyzed is at a 3 hour temporal resolution.

COSP Output to Compare Modeled Clouds to CALIPSO

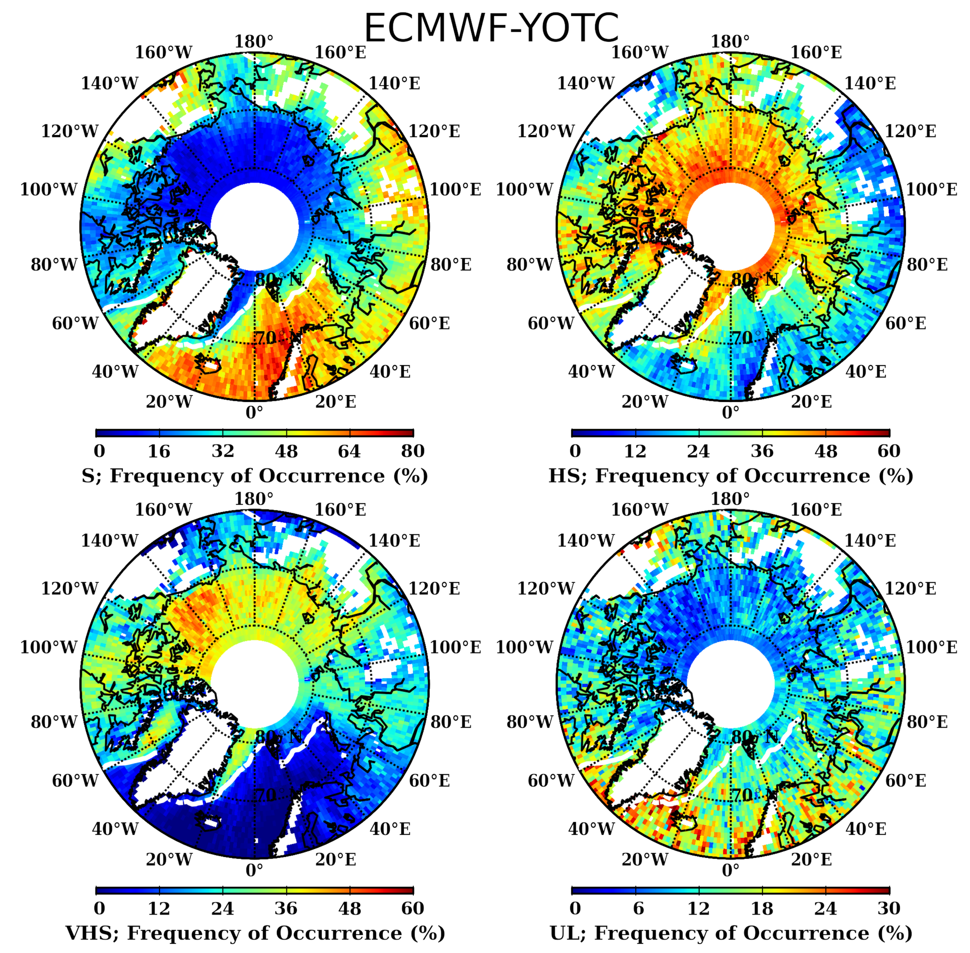


The CFMIP Observations Simulator Package (COSP) was run inline with CAM4 and CAM5 to compare the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) with the CALIPSO simulator output. The default cloud fraction for many climate models is parameterized by humidity, while cloud fractions from satellites are defined by the TOA radiative footprint or backscatter. COSP calculates cloud fractions in models by simulating what a satellite would observe. This leads to more of an apples-to-apples comparison between satellites and models. Since our focus is on Arctic clouds, which are largely low-level and thin, we examine cloud fractions from CALIPSO observations and the CALIPSO satellite simulator.

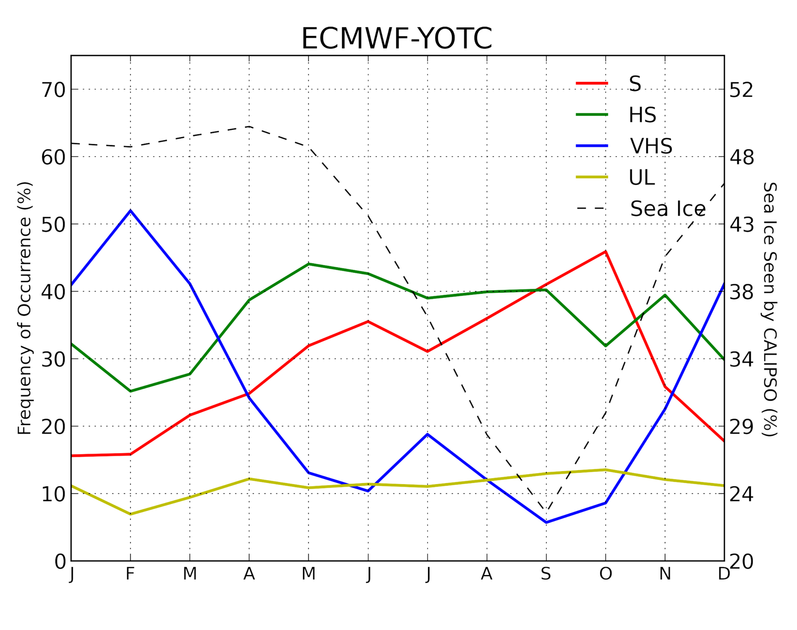
Arctic Synoptic Regimes: Role of Lower Tropospheric Stability



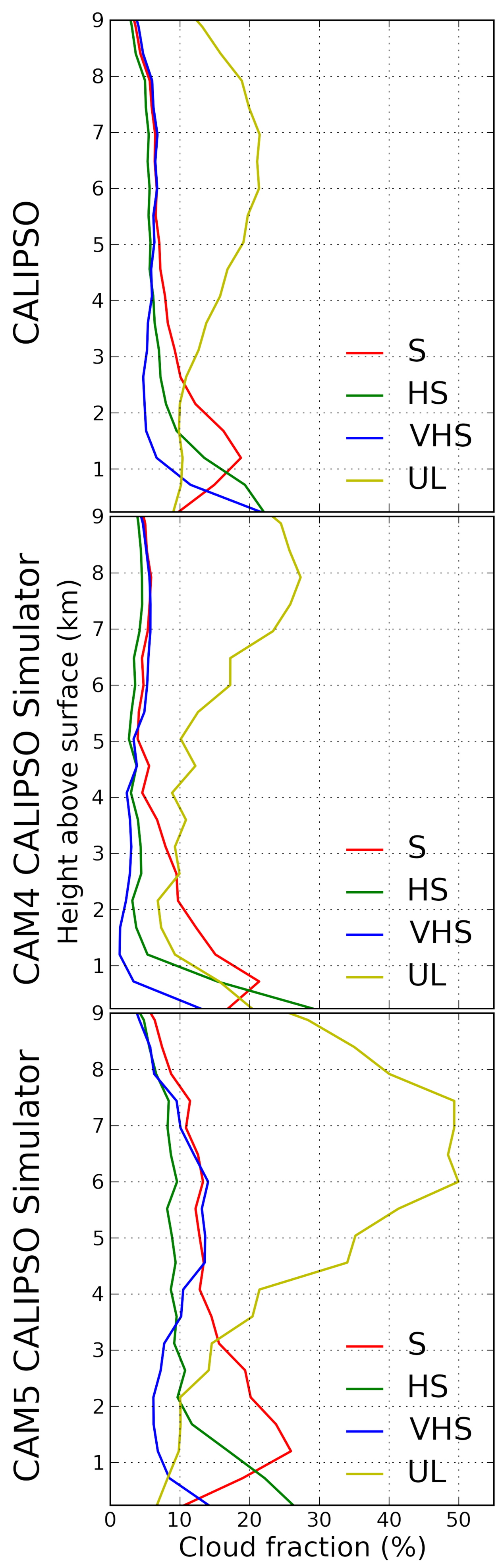
Four synoptic regimes were determined by performing *k*-means clustering on the variables lower tropospheric stability and mid-tropospheric uplift. The *k*-means clustering only occurred during periods when there was a CALIPSO over path defined by the 3 hour temporal data. The regimes were determined because large spatial and temporal differences occurred between these regimes. About 90% of the Arctic data consisted of periods of mid-tropospheric subsidence or very weak uplift. During these periods of subsidence, statistical significant different regimes were defined by differences in lower tropospheric stability. We call the four found regimes Stable (S), High Stability (HS), Very-High Stability (VHS), and UpLift (UL), and they occurred 29%, 36%, 24%, and 11% of the study period respectively.



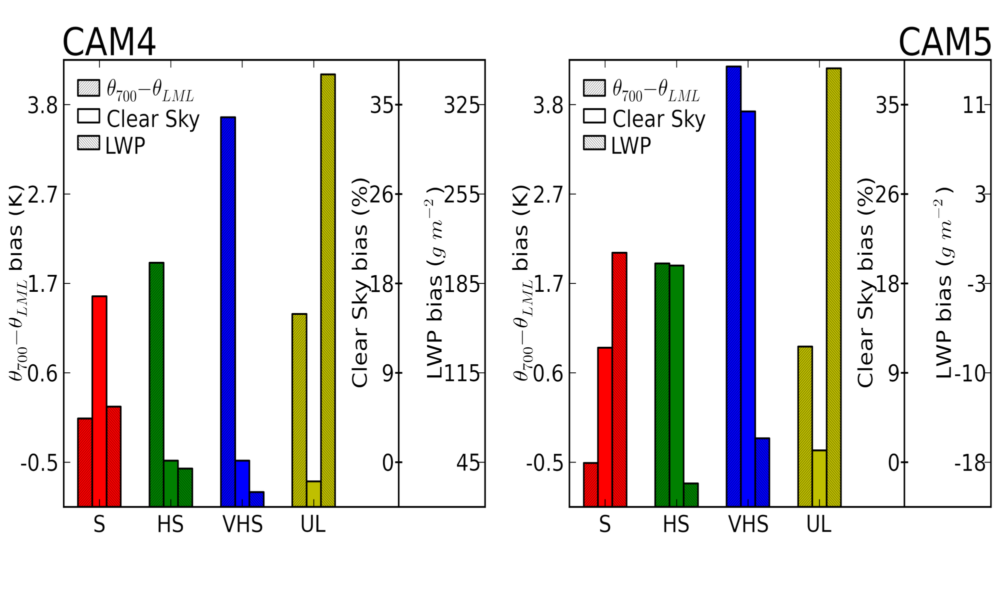
The white areas on the above maps represent regions in which the *k*-means clustering was not performed. These include regions poleward of 82°N due to the CALIPSO orbit and regions of high elevation. The stable regime occurred frequently over open water and during September and October. The high stability regime occurred frequently over sea ice. The very-high stability regime occurred frequently North of the Canadian Archipelago and during the winter months, and the uplift regime largely occurred near southern Greenland, and did not have much seasonal variance.



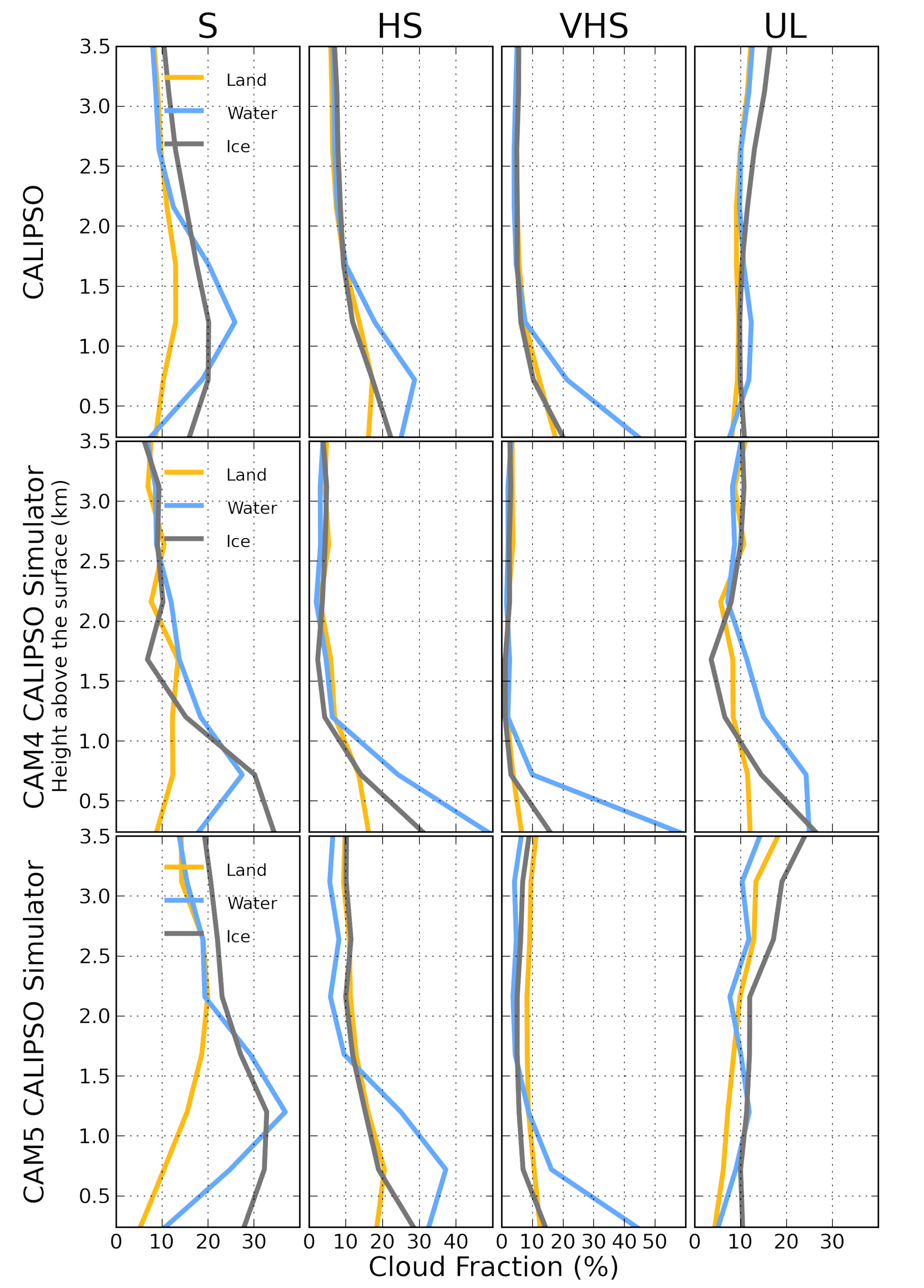
CAM5's Improved Sensitivity to Lower Tropospheric Stability



Increases in lower tropospheric stability resulted in the decrease of altitude of the maximum cloud fraction for the subsidence/weak uplift regimes. During the uplift regime cloud fractions greater than 20% occurred in the mid to upper troposphere. CAM5 produced the cloud profiles more similar to observations compared to CAM4 for the subsidence/ weak uplift regimes, but CAM5 had too large of upper level clouds fractions during uplift periods. CAM4 and CAM5 had larger lower tropospheric stabilities than the analysis data. CAM4 and CAM5 also had more periods of clear sky compared to the CALIPSO observations. Compared to surface data, the LWPs in CAM4 were much larger than observations. CAM5 LWPs were improved compared to CAM4, but CAM5 LWPS were too small.



CAM5's Improved Sensitivity to Arctic Surface Type



In going from sea ice to open ocean, the cloud amount increased at the lowest atmospheric level for all subsidence regimes except the least stable regime, and the height of maximum low clouds rose for all subsidence regimes except the most stable regime. CAM5 reproduced this covariability more accurately than CAM4.

Conclusions

- The *k*-means cluster algorithm successfully separated the Arctic into 4 synoptic regimes in which distinct cloud profiles occurred.
- Day 2 forecast output from CAM4 and CAM5 CAPT runs generally captured the same regimes as the ECMWF-YOTC analysis, but CAM4 and CAM5 drift toward a more stable lower troposphere.
- CAM5 reproduced the vertical cloud fraction profiles during subsidence periods more similar to observations compared to CAM4.
- The Arctic cloud response to the removal of sea ice was dependent on the dominant synoptic conditions and CAM5 reproduced this covariability better than CAM4.
- The improved boundary layer turbulence and cloud microphysical parameterizations of CAM5 resulted in more realistic low-level Arctic clouds during subsidence compared to CAM4.

Citation & Acknowledgements

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